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10/532448
JC20 Rec'd PCT/PTO 22 APR 2005

# LOAD DEPENDENT ANALYZING OPTICAL COMPONENTS

## BACKGROUND OF THE INVENTION

The present invention relates to load dependent analyzing optical components, in particular to interferometric phase measurement of passive and active optical components.

Optical networks operating at highest bit-rates, e.g. 40 Gb/s, impose increasingly stronger requirements on the dispersion properties of all involved network elements. This implies that passive and active optical components or devices need to be characterized, in particular in terms of group delay and differential group delay. Active components can be optical fiber amplifiers, such as erbium doped fiber amplifiers (EDFA), TDFA, OFA, optical wave guide amplifiers, such as EDWA, semi-conductor amplifiers, such as SOA, and hybrid devices. Major component parameters of active devices are gain and noise figure. These parameters can be measured by indirect principles such as time-domain extinction method, signal substitution and interpolation with signal subtraction and other direct principles such as dynamic gain and noise gain profile. Passive optical devices and their dispersion relevant phase properties can be measured by modulation phase shift methods, differential phase shift methods and interferometric methods.

## SUMMARY OF THE INVENTION

It is an object of the invention to provide improved load dependent analyzing optical components, in particular to interferometric phase measurement of passive and active optical components. The object is solved by the independent claims. Preferred embodiments are shown by the dependent claims.

Generally, interferometric methods used to obtain the phase properties of passive optical devices rely on the interference of a chirped laser light with its delayed signal. The present invention comprises the perception that active

components to be characterized by such interferometric methods must be loaded by a set of sources spaced in optical frequency. However, these loading sources interfere with the chirped laser in such a way, that phase properties of an active component can only be determined with significantly reduced accuracy. Advantageously, embodiments of the present invention allow for measuring the phase properties of active devices in the presence of loading sources without the aforementioned backlogs. Moreover, embodiments of the present invention provide the ability of measurements of group delay and differential group delay of active devices under load without a significantly reduced accuracy due to interference of the loading sources with the chirped probing laser signal.

Additionally, according to embodiments of the present invention the same interferometric measurement setup can be used for phase measurements, for gain and noise figure measurements, and for gain tilt and polarization dependent gain measurements, also. Therefore, embodiments of the present invention provide for a combined setup for loss, phase, gain and noise figure measurements.

The invention can be partly embodied or supported by one or more suitable software programs, which can be stored on or otherwise provided by any kind of data carrier, and which might be executed in or by any suitable data processing unit. Software programs or routines are preferably applied to the realization of the inventive method.

## BRIEF DESCRIPTION OF THE DRAWING

Other objects and many of the attendant advantages of the present invention will be readily appreciated and become better understood by reference to the following detailed description when considering in connection with the accompanied drawing. The components in the drawing are not necessarily to scale, emphasis instead being placed upon clearly illustrating the principles of the present invention. Features that are substantially or functionally equal or similar will be referred to with the same reference sign(s).

Fig. 1 shows a schematic illustration of an embodiment of the present invention.

## DETAILED DESCRIPTION OF PREFERRED EMBODIMENTS OF THE INVENTION

Referring now in greater detail to the drawing, Fig. 1 shows a setup 100 according to an embodiment of the present invention. Setup 100 comprises a bank 102 of sources 104 providing optical signals 106 which signals 106 are combined by a coupler 150 to a resulting signal 108. Sources 104 can be distributed feedback laser sources. Resulting signal 108 is amplitude modulated with a modulation frequency 109 by an external modulator 110 controlled via connecting line 129 by a radio frequency (RF) signal source 132. Signal 108 is then added to a measurement arm 111 of an interferometer 112 as a load signal for a device under test (DUT) 114 as a transmittive component to be analyzed in a measurement arm 111.

The DUT 114 can be an amplifier, e.g. an EDFA. The amplitude of the load signal 108 should be strong enough to induce a change of the load dependent properties of the DUT 114. Preferably, the load signal 108 should induce a saturation of the DUT 114.The other arm 116 of the interferometer 112 is a reference arm 116 of the interferometer 112.

Alternatively, the loading sources 104 can be modulated directly according to dotted line 105 or the DUT 114 can be modulated directly according to dotted line 107 if a loading source or a combination of loading sources together with a coupler is part of DUT 114.

Tuned laser light 115 provided by a chirped tunable laser source 117 is applied to the interferometer 112, also. The laser light 115 is split by a beam splitter 121 into a part 115a traveling through the measurement arm 111 in which it is delayed by DUT 114 and into a part 115b traveling through the reference arm 116. A delayed signal 120 is then superimposed with the undelayed part 115b of signal 115 by a beam splitter 123 to create a resulting interferometer signal

118.

Without the load 108, the interferometer signal 118 is determined by the interference of the laser signal 115b with its delayed signal 120. Typical frequencies of the interferometer signal 118 are up to 500kHz, e.g. in the range of 100 kHz – 500 kHz. The modulation frequency 109 of modulator 110 should be significantly higher than the maximum interference signal 118 obtained without the load 108. A modulation frequency 109 of > 5MHz is feasible.

A demodulator 122 controlled via connecting line 130 by the RF signal source 132 and receiving interference signal 118 passes the interferometer signal 118 to a receiver 124 at those times according to demodulation frequency 133, where the modulator 110 switches the loading light 108 off. The load dependent optical properties of the DUT 114 have a time constant that is larger than the off-period of the modulator 110. In other words: the modulation frequency 109 is chosen much higher than the frequency with which the load dependent optical properties of the DUT 114 are expected to oscillate. Therefore, optical properties of DUT 114 can be measured during the off-period of the modulator 110 without interference of laser light 115 of tunable laser source 117 with the load signals 108.

A signal 126 of the receiver 124 is then down-converted using classical heterodyne mixing by a mixer 128 into an interference frequency range used at no load operation of setup 100. The modulated receiver signal 126 is displayed in a graph 127.

Receiver signal 126 is mixed with signal 130 of the RF signal source 132 in mixer 128. The resulting mixed signal 134 is provided to a low-pass filter 136 and the low-passed filtered signal 138 is then provided to a signal processing unit 140 to evaluate group delay, differential group delay, gain and/or noise figure of DUT 114. In an alternative embodiment mixer 128 and low pass filter 136 can be replaced by a high-speed digital receiving unit.

In reference arm 116 there can be integrated a switch 119 to simulate a non-

interferometric time domain extinction method measurement of DUT 114, also.